

# THE DYNAMICS OF AIR TRANSPORTATION SYSTEM TRANSITION

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## Abstract

Both U.S. and European Air Transportation Systems face substantial challenges in transforming to meet future demand. This paper uses a feedback model to identify and describe key issues in the dynamics of system transition, with particular emphasis on stakeholder cost-benefit dynamics and processes for reviewing and implementing new system capabilities. Understanding of these dynamics is further reinforced through discussion of ADS-B and new runway construction examples. To implement the significant changes currently envisioned for ATM systems, it will be critical to structure system changes to anticipate and overcome stakeholder disagreements and improve the efficiency of the approval and implementation processes.

## 1 Introduction

The Air Transportation Systems in both the United States and Europe are facing several substantial challenges. Limited system capacity, in the face of continuously increasing demand for travel, poses one of the largest challenges to the continued operation of the US system. Future increases in traffic levels are projected to outstrip current capacity in several key points of the system potentially causing significant disruptions. In response to this anticipated demand increase and other pressures, both the U.S. Joint Planning and Development Office (JPDO) and EU SESAR (Single European Sky ATM Research) programs are proposing ambitious modernization goals for their respective domestic and international ATM systems. These modernization efforts must take place while also improving system safety and security, reducing environmental emissions, and involving multiple stakeholders in the decision process.

The purpose of this paper is to identify and discuss the dynamics of air transportation system transition, in order to understand the barriers to change that make such transitions difficult as well as the opportunities that exist to make transitions successful. Once barriers and possible

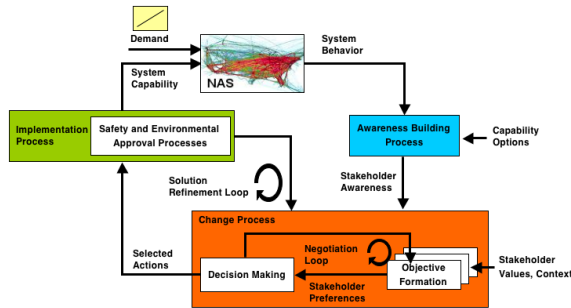
leverage points are identified and understood, problems during transition can be anticipated and strategies to mitigate their effect can be developed. The paper details why barriers occur, where along the transition process they can be expected, how they work, and what the implications are. In addition, the paper identifies opportunities that exist for addressing such barriers. Understanding and anticipating issues that may arise during transition is critical to achieving the required increases in system performance proposed by JPDO and SESAR to meet future demands.

Transition dynamics and barriers are discussed using a model developed based on past cases of transition. While the specific examples discussed derive from US experiences, the general barriers and dynamics identified are applicable both to US and European efforts to modernize Air Traffic Management. Two examples of system improvements are used to illustrate specific aspects of system transition. The examples were chosen because they represent possible solutions for addressing capacity concerns. Both are also examples of currently undergoing or planned transitions in the US Air Transportation system. The first example is Automatic Dependent Surveillance Broadcast (ADS-B). ADS-B is an integrated set of airborne and ground components that provide the position of aircraft as a replacement or complement to radar-based surveillance. The ADS-B datalink also enables the receipt of information from other aircraft or the ground. ADS-B is the pathfinder example for technology modernization included in JPDO's Next Generation Air Transportation System [1]. The second example discussed will be runway expansion, a crucial activity for expanding airport capacity outlined in FAA's Operational Evolution Plan (OEP) [2].

## 2 Transition Model

In order to understand the barriers to transition in the air transportation system a feedback model of transition is used. The model, presented in Figure 1, was developed based on 13 cases of historical transition efforts in the US Air Transportation System. Cases studied include tech-

nology and policy changes, successful and unsuccessful changes, as well as safety and capacity driven changes. The framework provided by the model is used to study barriers caused by the multi-stakeholder nature of transition as well as those posed by the complexity of the implementation process.



**Figure 1. Transition Model**

Boxes in the model represent high-level processes while arrows represent the resulting states. The Air Transportation System is represented as a process in the model, the output of which is system behavior. These outputs are monitored as part of the awareness building process. During the awareness building process, stakeholders (a stakeholder is anyone with an interest in the outcome or involved in the process of a transition) develop an understanding and definition of the problem and potential solutions. Each stakeholder forms their own mental model of the situation. This includes projecting future outcomes based on potential actions to address the problem.

Once stakeholder awareness of a problem and potential solutions exist, stakeholders engage in the change process. During this process, stakeholders evaluate the projections for the future and develop preferences based on the formation of their individual objectives. While these preferences are determined separately for each stakeholder, they can be modified as stakeholders act and interact during the decision making process. The change process terminates when an action to address an issue is selected, often by the stakeholder with authoritative power.

Once an action is selected, it proceeds through the implementation process. In this process, stakeholders allocate money, refine the details of the solution, and approve the chosen solutions. Once implementation is complete and successful, the capability of the system is improved and the problem being addressed is reduced or eliminated. However, barriers to change can arise in multiple places in the model and stall or even derail change efforts. In particular, the multi-stakeholder nature of the change process as well as the complexities of implementation can pose bar-

riers to change. These barriers are captured in the negotiation and solution refinement loops shown in the model and discussed below.

The negotiation loop occurs during the change process and captures the dynamics of decision selection in a situation with multiple stakeholders who have different agendas, value structures, and are effected differently by potential changes to the system. During this process stakeholders work to influence decision makers and interact with others to determine if concessions and agreements can be reached. Inability to overcome strong stakeholder oppositions can contribute to long transition time constants.

Barriers can also arise during the implementation process. The complexities of determining the specifics of a solution as well as conducting the necessary safety, environmental, and other approval processes can delay change. In addition, stakeholder disputes can once again arise when details of a solution are being determined. Finally, the approval processes that occur during implementation can be deliberately used by stakeholders who are negatively affected by a change but were unable to influence decision makers against its implementation.

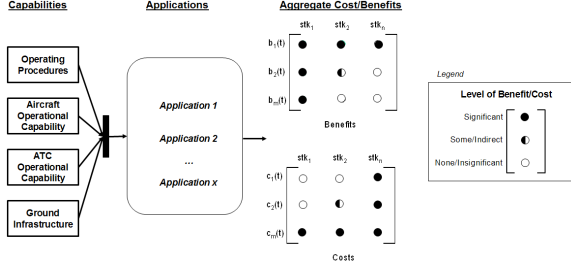
Several key issues which arise during system transition will be discussed in the context of the model in the following sections.

### 3 Stakeholder Objectives and Decision Making

#### 3.1 Stakeholder Cost-Benefit Dynamics

The distribution of costs and benefits can have a significant impact on the stakeholder dynamics during the process of transition. Understanding and anticipating stakeholder dynamics by analyzing the distribution of costs and benefits to stakeholders is an important aspect of achieving successful transitions. Marais and Weigel [3] provide a framework for discussing cost-benefit dynamics through the utilization of cost-benefit matrices. This framework can be expanded, as shown in Figure 2, to illustrate that the distribution of costs and benefits is influenced by the applications that stem from a proposed capability change in the system.

As shown in the figure, a new system capability can be decomposed into operating procedures, aircraft operational capability (i.e. equipage), ATC operational capability, and ground infrastructure changes. These capabilities then enable new applications from which stakeholders derive benefits. The new capabilities also need to be

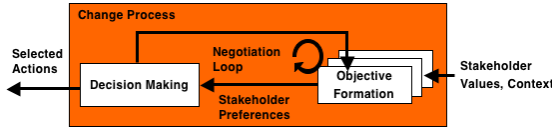


**Figure 2. Transitioning from Capabilities to Benefits**

financed. As a result, the benefits that can be achieved come at a cost.

### 3.2 Decision Making

When an opportunity or need for system transition exists, stakeholders determine their objectives based on how they will be affected by different possible actions. Such value analysis may be determined by a rigorous analysis of costs and benefits or can be merely *perceived* by a stakeholder. These objectives determine what a stakeholder wants to accomplish during the change process shown in Figure 3.



**Figure 3. Stakeholder Negotiation Loop**

Engaging in the change process requires interaction and negotiation between stakeholders to make a decision and select an action. The ability of stakeholders to arrive successfully at a decision depends not only on how much disparity exists between the objectives of different stakeholders, but also the relative power of each stakeholder in influencing decision making. The process of transition can stall at any point during the negotiation loop, because stakeholders are unable to resolve their differences on problem understanding, the correct action to address the problem, or the details of how a selected action should be implemented. However, successful transition can be facilitated through incentives or other measures that better distribute stakeholder benefits and costs. These measures can be used during the negotiation loop to help accelerate the change process and foster acceptance of a solution.

Stakeholder dynamics can also change throughout the transition process. For example, the level of system equipage can change the cost benefit structure for stake-

holders still deciding whether or not to equip. In addition, shocks to the system can cause stakeholder changes in cost-benefit evaluations and in relative power. Major accidents can highlight an underlying system deficiency and generate sufficient public pressure to change. Many safety technologies, such as TCAS and EGPWS, were implemented to address problems highlighted by such accidents.

In the following sections, the distribution of costs and benefits as well as how that distribution influenced stakeholder dynamics during the change process are discussed for three example cases. Aggregate costs and benefits of potential applications are discussed for the Capstone ADS-B project and for runway expansion at Boston Logan International Airport, while detailed benefits by application are discussed for ADS-B implementation in the Gulf of Mexico.

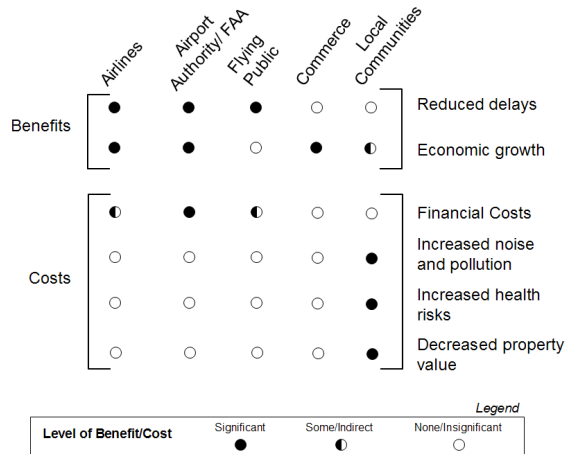
### 3.3 Asymmetrical Cost and Benefit Distribution: The Case of Runway Construction

An example where differences in stakeholder preferences impede change is in airport expansion. Many airports are currently facing capacity constraints as well as increasing demand, resulting in increased delays. As part of the FAA Operational Evaluation Plan a number of these airports are attempting to expand runway capacity by extending or adding runways. However in many cases these projects have been met with strong community opposition.

Applying the framework presented in Section 3.1, decreasing airport delays by increasing capacity would be the new capability added by the transition. The application that achieves this capability is a new runway or extended runway. The distribution of benefits and costs between different stakeholders are shown in Figure 4.

Relevant stakeholders include the airlines which operate at an airport in question, the local airport authority, the flying public (specifically those who use the airport), commerce groups, local communities living around the airport and the groups representing them, local government, and the FAA. The local government is not included in the cost-benefit matrix because it is not directly impacted by the construction of the runway, but acts indirectly in the process. Local governments are lobbied by local communities, commerce groups, as well as port authorities and airport users. They are also elected by members of all or some of these groups and have a responsibility to represent their interests.

The reason for community opposition is apparent from the cost-benefit distributions shown in Figure 4. Communities perceive themselves as paying most of the non



**Figure 4. Perceived Aggregate Cost Benefit Matrices for Airport Runway Expansion Projects**

financial costs of the runway, such as increased noise and pollution, while the benefits extend mostly to other groups. Benefits to communities that result from airport expansion are less clear. Strong air transportation is tied to the economic health of regions and can induce economic growth and development, but the effects are difficult to measure and therefore are not apparent to communities as a tangible benefit.

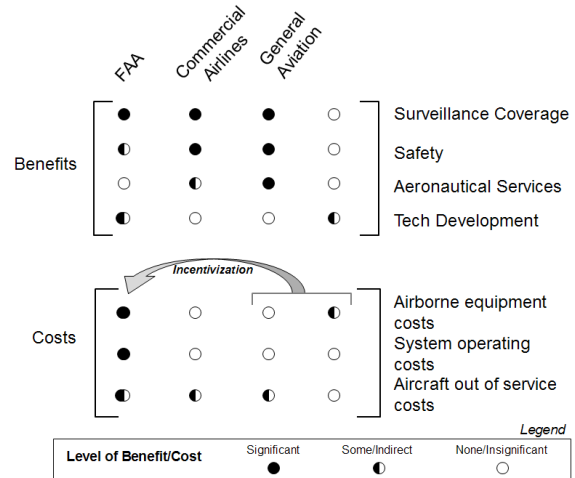
There have been successful cases of airport expansion projects. In these cases the communities are often more removed from the airport. In addition, interested parties anticipate potential stakeholder opposition and mitigate the adverse effects to communities. In successful examples, such as projects in Atlanta or St Louis, the addition of a new runway can take about 10 years. However, there are also cases such as Boston and Seattle where community opposition is very difficult to overcome and expansion projects can stall for as much as 30 years even when mitigation measures such as sound proofing are implemented and compromises on runway usage are made [4, 5].

### 3.4 The Role of Incentives: ADS-B Capstone Project

The Alaska Capstone project was an early demonstration program for ADS-B capabilities, and today continues as part of the current plans to implement ADS-B throughout the NAS. Several factors make Alaska an ideal location for demonstration projects, and ADS-B in particular. These factors include a lack of surveillance coverage in some areas, remote and inhospitable terrain, and harsh

weather conditions [6]. Potential safety improvements, combined with strong political support provided an opportunity to deploy and certify prototype ADS-B capabilities early in the development lifecycle through the Capstone project.

During Capstone, aircraft were voluntarily equipped with an IFR certified GPS receiver, Multifunction Display, and associated ADS-B data-link and avionics, with reimbursement from the FAA. At the same time, the FAA worked with avionics manufacturers to support technological implementation of ADS-B avionics, deployed ground-based transceivers (GBTs), and integrated ADS-B reports into the air traffic control system. Specific capabilities provided in Capstone included the broadcast of aircraft position to ATC, up-linked traffic, weather, and aeronautical information (e.g. NOTAMs). The applications provided included surveillance outside of existing radar coverage and increased onboard situation awareness [7]. The aggregate benefits provided by these applications compared to the costs incurred are shown in Figure 5. As a demonstration program, equipage was incentivized by the FAA who covered costs that would have normally been borne by operators and avionics manufacturers. As a result, benefits were provided at little perceived cost to the aircraft operators.



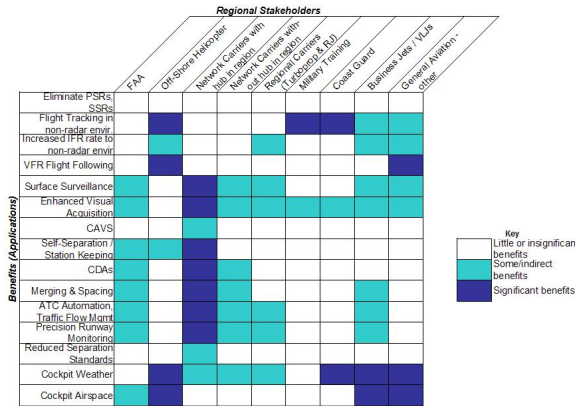
**Figure 5. Aggregate Cost Benefit Matrices for the Capstone Project in Alaska**

The Capstone project in Alaska presented a case where stakeholder alignment was achieved with the use of incentives. Another effect of this alignment was a rapidly accelerated timetable for certification, procedure development, and deployment of ADS-B capability. Capstone components and procedures were certified and implemented

rapidly, from initial definition and funding in 1999 to operational capability in 2001 [7].

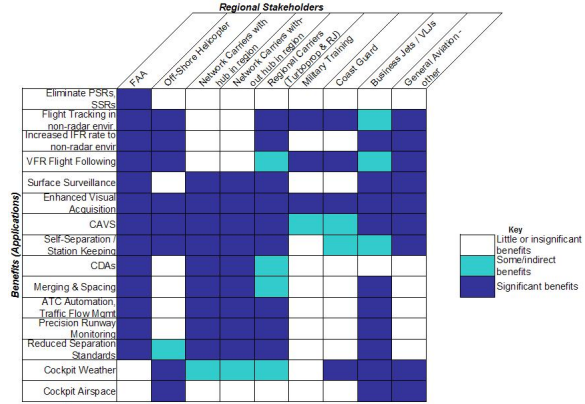
### 3.5 Temporal Evolution of Costs and Benefits: ADS-B Deployment in the Gulf of Mexico

In some cases, costs and benefits of a set of enabled applications can change as the transition progresses, usually through varying levels of equipage. The FAA is introducing ADS-B, GBTs, and services regionally, with the Gulf of Mexico as one of the first locations. Deployment in the Gulf of Mexico provides immediate benefits to operators and the FAA due to the lack of radar coverage, and an opportunity to place ground stations on oil platforms already located in the Gulf [8]. Investigating the planned deployment of ASD-B in the Gulf of Mexico provides a notional illustration of how benefit distributions can change substantially with the rate of user equipage. Matrices of application-level benefits by stakeholder for ADS-B implementation in the Gulf region are presented in Figures 6 and 7 for an assumed 1/3 (partial) equipage state and full equipage respectively.



**Figure 6. Application Benefits Matrix for Gulf of Mexico (1/3 Equipage)**

Figure 6 shows benefit levels to operators and the FAA who are early adopters, assuming approximately 1/3 of total flights are ADS-B out equipped, but full ground infrastructure capability is present. These early adopters primarily receive benefits when they comprise a large fraction of the flights into and out of an airport (network carriers with hub in region) or when applications are provided proportional to fleet equipage (e.g. enhanced visual acquisition, cockpit weather, fleet tracking). Specific to the Gulf of Mexico, off-shore helicopter operators would initially benefit from fleet tracking and radar-like IFR separation applications. All operators could initially benefit from enhanced visual acquisition of traffic, leading to in-



**Figure 7. Application Benefits Matrix for Gulf of Mexico (Full Equipage)**

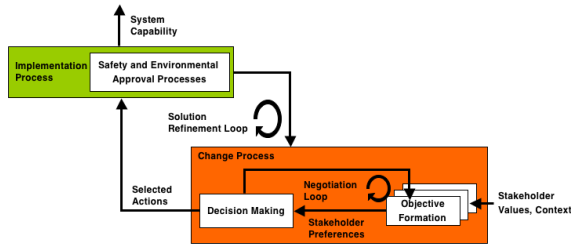
creased safety and possibly increased capacity in VFR and MVFR conditions.

Figure 7 depicts the benefits to operators and the FAA after full ground station implementation and operator equipage. Most benefits are provided to all operators and are realized since the critical mass has been met and all ADS-B applications can be performed. The FAA realizes few benefits are available until the critical mass is reached and current procedural separation standards can be replaced with increased capacity through radar-like separation services. Because benefits to stakeholders increase significantly as more operators equip, this example illustrates a strong case for using of incentives to accelerate fleet equipage and gain full benefits as rapidly as possible.

## 4 Complexities of the Implementation Process

Once an action has been selected during the change process, it needs to be implemented. The selected action is often a broad commitment to a new technology or implemented system and many steps still need to take place before implementation is complete. The complexities of the safety and approval process, while necessary, can introduce substantial delays into the transition process by initiating the solution refinement loop shown in Figure 8. A critical aspect of achieving system transitions envisioned in NGATS and SESAR will be the ability to obtain safety and environmental approval for new capabilities. In particular, safety certification and approval poses a significant risk in system transition. A high level abstraction of the approval steps required for various aspects of system capabilities is shown in Figure 9.





**Figure 8. Solution Refinement Process**

#### 4.1 Safety Review Processes

Once an overall concept of action exists, detailed plans have to be made and carried out in the implementation process. In fulfilling their commitment to public safety, national regulatory authorities must ensure that the proposed ATM system change can be accomplished at an acceptable level of safety. To provide this assurance, the safety authorities carry out a variety of oversight functions focused on several aspects of the proposed change. Figure 9 shows a simplified version of the approval process that occurs during implementation.

An improvement in the operating performance of the system can be decomposed as four basic areas: aircraft operational capability, ground infrastructure, air traffic control capability, and established operating procedures. As an example, achieving ADS-B-based separation procedures requires several supporting system capabilities: airborne equipage to enable ADS-B out, ADS-B ground stations to collect and rebroadcast ADS-B data and transmit to ATC, air traffic control capability to receive and display ADS-B traffic data, and defined separation procedures using ADS-B data are all necessary. The characteristics of each of these components are defined by the system specification and definition and each separate component and their interactions must be certified by the regulatory authority as meeting safety requirements.

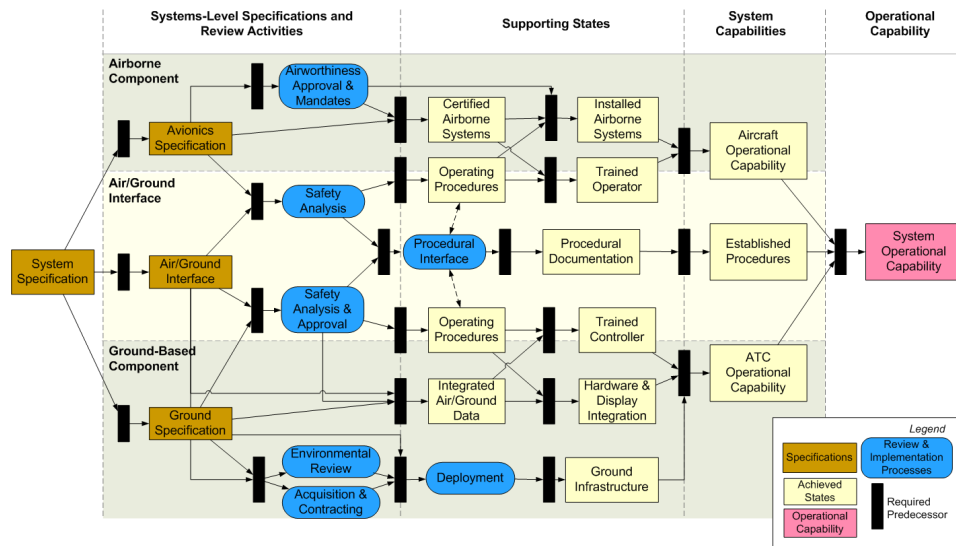
The changes envisioned by JPDO and SESAR for system capabilities are broad in scope and involve changes in multiple areas of the system, including avionics, ground infrastructure, and the air/ground interface of data integration and operational procedures. To manage complexities in the scope of change, regulatory authorities carry out a variety of oversight functions based on a decomposition of the system. Figure 9 shows the processes and states broken down in this manner, with the ultimate goal of achieving desired system capabilities in three basic areas: aircraft operational capabilities, air traffic control operational capability, and established procedures.

In order to carry out the certification process, resources must be allocated to be spent on analysis in different areas of the system. Within the FAA, the Air Traffic Organization is responsible for the performance of the air traffic control system, while the Aviation Safety organization evaluates aircraft certification and changes to flight and operating rules. In the safety analysis process, technical expertise is also often required from air traffic controllers, aircraft operators, and other users of the system. This review process can often take a substantial amount of resources and effort and require numerous iterations of system capabilities and requirements. A large amount of analysis may be necessary in order to sufficiently prove that a system meets required safety performance, and in many cases limited operational implementations are used to understand safety consequences.

The two previous ADS-B examples discussed in this paper showed stakeholder cost-benefit dynamics in limited deployment of ADS-B technology. Each implementation is also an example of the opportunity to identify and understand potential operational safety issues from experience. The Capstone program initiated the technical definition of ADS-B and related service delivery architecture. Because of its status as a demonstration program, and other accelerating factors, the system approval, avionics development, and implementation proceeded rapidly. Safety review processes were begun in 1999 and operations with ADS-B commenced in Alaska in 2001 [7].

Early deployments provide an opportunity to gather data on the efficacy of the system, to mature technology, and to understand safety risks that were not anticipated in earlier review and analysis. This approach manages the complexity of implementation by controlling conditions in a limited environment and involving fewer stakeholders in the decision-making process. Similarly, the deployment of ADS-B in the Gulf of Mexico will provide an opportunity to attempt implementation at a smaller scale and learn about possible issues that may arise during a larger scale deployment. However, before ADS-B benefits can be fully realized, there is a significant amount of analysis that must still be performed to ensure safety under the conditions of system-wide implementation. Some of this analysis is likely to duplicate effort already performed in evaluating the previous implementations. Transfer of knowledge is crucial to eliminating such inefficiencies and improving the implementation process.

The broad scope of change also requires significant coordination across responsibilities within the regulatory authority, which can require substantial resource investment. Eliminating delays and improving efficiency is important both to keep up with the rapid pace of technology devel-



**Figure 9. Highly Simplified Approval Processes Necessary for Improved Operational Capabilities**

opment and to certify the large number of new operating capabilities required to increase capacity. This will enable the implementation process to flow efficiently, so that value can be delivered to multiple stakeholders in the NAS.

#### 4.2 The Environmental Review Process

In addition to the safety review process, the environmental review process is necessary for runway and other infrastructure projects. This process exists in order to ensure that projects do not pose too large a threat to the health of surrounding communities and the global environment. For any runway project, the environmental review process takes place once the preliminary design is complete. This includes the layout, costs, benefits, and possible alternatives for the project. The first step of this process is to conduct an environmental assessment to determine if the project will have significant impact on noise, air quality, water quality, or historical artifacts. If the answer is no, and all state regulations have been met, a project can proceed to acquire permits and then begin construction. However, if significant impacts are expected an Environmental Impact Statement (EIS) must be prepared. A notice of intent is first required, followed by a draft EIS which is reviewed by interested stakeholders including the public. Incorporating comments from the review process, a final EIS is prepared and submitted for review. If the statement is approved a record of decision is issued and the project can proceed to permitting and construction [9].

The environmental review process can take several years including time to prepare, review, and approve the

environmental impact statement. This can add a significant amount of time to the overall transition process. In addition, the EIS is often used by those opposing a runway project as the object of litigation thereby further delaying construction.

A study conducted by the General Accounting Office surveyed the top 50 airports in the US. 92% of study participants said that it was more difficult to balance environmental concerns with airport operations than it was in 1989. Noise was listed as the largest concern by 58% of participants, followed by water quality listed by 24% of participants, and local land and air issues listed by 16%. 88% of the participants stated that the environmental review process contributed to delaying runway projects and 72% said that it was the primary cause of delay. The median time for an airport project amount the participating airports was 10 years [10].

The FAA Operational Evaluation Plan (OEP) is a plan to expand existing airports. Figure 10 shows the airports with recent and current OEP projects as compared to the top 30 most congested airports in the country. The figure shows that only a small fraction of the airports that are congested are attempting to expand capacity. This indicates that more construction projects will be needed in the future as demand continues to increase. However, with lengthy construction times these projects may not be realized in time to accommodate the growth rate. The figure includes both pending and completed projects and the number of years since initiation. It can be seen that runway projects can take about 10 years to complete in the best case and almost 30 years in the worst case.



**Figure 10. OEP Airport Projects**

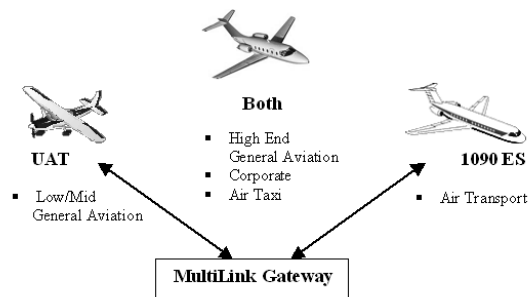
One way to help resolve stakeholder issues is to make redesigning projects easier. Currently, the environmental review process can pose a barrier to resolving stakeholder conflicts when redesigning a construction project would mean that the environmental approval process would have to be redone, causing a delay. Methods for revising and iterating on the design of runway projects, while maintaining the validity of the environmental impact statement, could be developed to make the process more efficient.

#### 4.3 Stakeholder Differences during Implementation

During the implementation process, stakeholder issues remain important to the dynamics of change. Although stakeholders may have agreed to an overall plan of action, they also need to agree to the details of implementation and their roles in it. Implementation requires making detailed plans and schedules: technical issues need to be resolved, stakeholders need to agree on budgets and the distribution of costs, as well as timetables for development, testing and implementation. Each of these actions can act as a barrier to forward progress delaying or stalling the transition process. The issues dealing with stakeholder differences during the implementation process are captured in the refinement loop in Figure 8, which can become a delay loop in the transition process.

In the case of ADS-B, stakeholder differences have impacted the architecture of the broadcast communication standard. Three candidate technologies were initially considered to provide transmission and reception of ADS data: Voice Data Link Mode 4 (VDL Mode-4), 1090 Extended Squitter (1090ES), and the Universal Access Transceiver (UAT). After a cost-benefit analysis [11], VDL Mode 4 was ruled out in cost and benefits, UAT was shown to be less expensive for GA operations and offer a higher bandwidth for uplink of graphical weather infor-

mation, and 1090ES was shown to be roughly equivalent in performance but would be less expensive for air carriers because they are already equipped with 1090-Mhz capable Mode S transponder. The final decision in the US was to support ADS-B through both protocols. The decision to support both protocols required the addition of a “MultiLink Gateway” to all ground stations so that UAT traffic information is uplinked to 1090ES equipped aircraft and 1090ES traffic information is uplinked to UAT equipped aircraft, eliminating the ability to perform air to air separation applications without working ground stations. The consequence of this decision is shown in Figure 11, indicating the uncertainty in link equipage applicability for medium-sized aircraft.



**Figure 11. ADS-B Communication Standards [12]**

In addition to choosing the link technology, choosing a standard protocol on that link has been problematic for stakeholders. The initial ADS-B system performance standards (MASPS) were developed by RTCA as DO-242. However, limitations and issues with this protocol were discovered. In particular, the way in which GPS integrity and accuracy is characterized proved to be an issue [13]. This led to DO-242A, a newer protocol that resolves many of the problems found with the original standard. However, avionics manufactures and operators have been hesitant to implement the DO-242A standard in equipment because of uncertainty in which standard the FAA will support, or if stakeholders will revise the ADS-B MASPS again in the future.

In addition to agreeing on the technical details of a solution, it is also necessary that individual stakeholders commit to fulfilling their part of the implementation plan. For example, carriers may be required to equip aircraft with a specific technology. They can be reluctant to do so if such equipage is not perceived as being in their benefit. In addition, stakeholder may not want to commit to paying and carrying out their share if the benefits they are expecting also depend that another party do the same. There have been past examples where the FAA required airlines to equip their aircraft but never delivered the in-



infrastructure to make the equipage beneficial or even useful leading to mistrust. Commercial airlines mistrust the FAA's ability to deliver infrastructure following the failure of CPDLC, and general aviation has similar concerns following the FAA's decision to not mandate the Mode-S transponder. These past examples are leading carriers to question whether or not the FAA will deliver the necessary infrastructure, and if it does so whether or not carriers will truly see a benefit or if the FAA will be the only one to see a drop in costs.

One way to get past stakeholder hesitancy is to once again use incentives to equip or carry out whatever necessary actions. Incentives can change the cost benefit structure for a stakeholder and as a result change their objectives making the decision to act more in their benefit. Mitigation measures can also be used to help offset the effect of costs which may disproportionately affect a subset of stakeholders.

Mandates can also be used to move past stakeholder barriers. This can be an effective means of bringing about change when a stakeholder with the authority to mandate a change exists. A mandate can clarify the details of a transition and as a result eliminate uncertainty from the cost-benefit analysis carried out by stakeholders. Eliminating such uncertainty and clarifying benefits can make stakeholders more willing to equip. However, in order for a mandate to be successful, stakeholders have to trust that the mandating party will fulfill their part of the transition.

#### *4.4 Deliberate Blocking of Transition*

Even with the use of mitigation, not all stakeholders can be convinced to accept a change. Those stakeholders that feel they would lose significantly by the implementation of a proposed change have a large stake in continuing a fight even when a decision has been agreed on by others. Stakeholders most likely to try to block implementation are those who were marginalized or not represented at the original decision process or those who believe that the selected solution is so negative to them that the status quo is preferable to the change. Such stakeholders also usually do not have the ability to unilaterally change the decision. As a result, their objective becomes to get in the way of implementation in the hopes of preventing implementation or maybe restarting negotiations.

Stakeholders can build support and coalitions, in some cases attempting to involve the public or lawmakers. This can increase the power asserted in favor of a particular solution or even any solution. To do this, they need to frame the argument in a way that gets the attention of others. A standard framing tactic is the use of established values that others will resonate with. In the policy arena com-

mon values used to frame disputes are equity, efficiency, security, liberty, and community [14]. In the air transportation system a powerful value is safety. Maintaining and promoting safety has been one of the main goals of the system since its inception and many past changes occurred because of safety drivers. In particular, accidents provide a powerful catalyzing event for change. They create widespread awareness and engage the general public who in turn engage legislators. Because it is such a strong value, it can also be used to block change. All a stakeholder needs to do is to successfully create doubts about a proposed change's safety and that change will be delayed or even canceled.

The Capstone project provides an example where the "safety veto" was used twice. In March 2006, ADS-B returns were removed from controllers' display screens in the Anchorage center due to controller concerns about discriminating between aircraft radar returns and ADS-B equipped returns [15]. The Alaska Aviation Coordination Council, a group that represents commercial operators in the area, was concerned with the safety implications of lack of ADS-B data for controllers. Based on these concerns, the FAA evaluated ADS-B to radar procedures and returned ADS-B returns to controllers' scopes in May [15]. In this case, safety was used as an argument both to oppose the specific use of ADS-B procedures and then to reinstate them.

Another tactic for preventing or stalling change is to argue about the validity of data, models, or predictions. Discrediting the basis of the understanding of the problem as well as the basis for evaluating the effects of solutions can stall the process or send it back to earlier stages. This technique was used in the fight over the construction of runway 14/32 at Logan airport in Boston: the runway opened on Thanksgiving Day in 2006, but a series of litigation between the local port authority and affected communities delayed the project for 30 years [4]. The fights focused in no small part around the assumptions made in predicting the effects that the runway would have on local communities.

Unfortunately, models and especially predictions always contain assumptions which can be attacked. Issues of credible knowledge assessment becomes a powerful tool in policy disputes. It raises the question of how accurate models have to be, and also who has the credibility use them and be believed.

When stakeholder differences become entrenched, and a marginalized stakeholder cannot be pacified with mitigation, stagnation of a transition can occur. As a result, the time to bring a change about can increase significantly.

## 5 Implications of Long Implementation Time

Long implementation times can have the consequence of rendering transition efforts irrelevant. The rapid pace of technology development means that the next generation solution could be developed and available before the existing solution can be implemented in the NAS. This may force stakeholders to decide to abandon an existing system and try to begin again with the new technology. The problem with such a strategy is that it can occur repeatedly as technology development progresses and the transition process is restarted with each new development.

An example of the effect of technological improvements relates to the ADS-B dual link decision. Since the 2001 dual link decision in the US, rapid evolution in technology has undercut the assumptions in the dual-link decision. 1090ES equipment can be manufactured and installed in small aircraft at a similar cost and size as UAT equipment. Also, in-cockpit satellite-based weather services have grown rapidly in the general aviation industry, providing an alternative to the weather products provided by UAT. As a response to technological improvements, a contractor has proposed a single 1090ES system supplemented with commercial satellite-based in-cockpit weather. This has the potential to eliminate the complexity of multilink gateways in the ground infrastructure [16], but would require revisiting approval processes.

Long implementation times can also mean that problems become moot before they are addressed because the environment has changed or stakeholders have adapted in a number of other small ways. Examples include the Microwave Landing System (MLS) and expansion projects in Saint Louis (STL) where expected demand did not materialize. While this can be beneficial because a problem has been solved, it may be that small local solutions have been put in place and are inefficient for the system as a whole. Even in cases where the adaptations have proved to be successful and efficient, a transition process may not be halted just because the problem no longer exists. In these cases, money will still be spent on the original attempted solution.

In the case of runway and infrastructure expansion long implementation times mean that capacity increases are not made in time to support demand. In such a case, managing demand will be the only option available which can be implemented rapidly. Figure 12 shows how demand management would modify the demand input into the system transition model. Demand management is already in place at 4 slot restricted airports in the US. In these cases slot restrictions were implemented as emergency measures and

have remained in place. Recently political pressure resulted in an attempt to remove restrictions at two of the airports, but without success. As a result of slot removal in 2000, LaGuardia suffered crippling delays and slots had to be reinstated [17]. Currently, plans for how to best distribute the limited resources at these airports in an efficient and equitable manner are still being made.

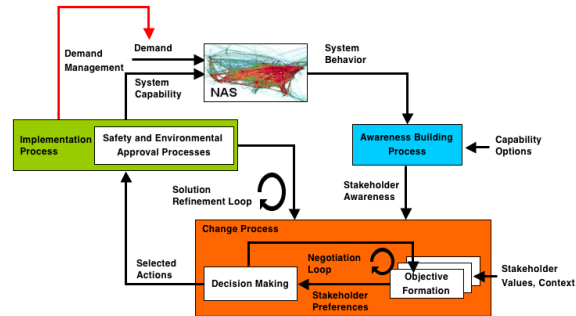


Figure 12. Demand Management

## 6 Conclusions

A critical enabler to bringing about the next generation air transportation system in the US and in Europe is the ability to strategically and effectively transition the air transportation system. Stakeholder opposition to change as well as the complexities of the implementation process both pose significant barriers to change. Effective means of using incentives and mitigation need to be developed in order to move past stakeholder barriers. In addition, it is critical that efficient safety and environmental review processes be developed in order to faster implement new capabilities into the air transportation system.

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## Key words

cost-benefit, system transition, stakeholder, ADS-B, runway expansion, air transportation

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